

INTERLEAVING METHOD FOR SHORT BURST ERROR CORRECTION IN HIGH
DENSITY DIGITAL VERSATILE DISK

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a digital versatile disk (DVD) technology, and more particularly, to a method for formatting and interleaving error correction blocks adaptively for improving a capability of correcting short burst errors in a high density DVD.

2. Description of the Related Art

In general, DVDs are largely categorized as two types; read only DVDs and read and rewritable DVDs. The information storage on a read only type optical disk is realized by forming grooves called pits on the surface of the disk, "0" is assigned to represent a pit portion, and "1" is assigned to represent a non-pit portion (that is, a land). During reproduction, a laser is irradiated onto tracks of the disk, and "0" and "1" are distinguished according to a difference in the light reflectivity. For example, in a rewritable-and-erasable phase-transition optical disk, a recording layer of the disk undergoes structural transformation between crystalline and amorphous states by the heat generated from the laser. There are significant differences between the reflectivity of these two states, which correspond to "1" and "0", respectively. The recording layer can be selectively changed into either a crystalline state or an amorphous state by adjusting the power of a laser during recording.

Errors generated at a DVD disk include random errors occurring to all channels, short burst errors due to dust or foreign matter, long burst errors due to scratches, or the like. To correct such errors, a conventional DVD error correction system employs a Reed-Solomon Product code. For example, in a digital versatile disk recorder (DVDR) having a storage capacity of 4.7 GB, in order to reduce correlation between adjacent data of data blocks, scrambling is performed on data blocks, and 16 sectors constituting each data block are grouped into a size of 12×172 bytes to form a data block of 192×172 bytes, as shown in FIG. 2. Then, RS (208, 192, 17) encoding is performed in a column direction to generate an outer code parity of 16 bytes (PO), and RS (182, 172, 11) encoding is performed in a row direction to generate an inner code parity of 10 bytes (PI), thereby forming a 208×182 byte ECC block.

After obtaining the ECC block in such a manner, row interleaving is performed such that each PO portion is interleaved for every 12 rows, that is, at the end of the last row of each sector, as shown in FIG. 3. According to the conventional interleaving method, data can be transmitted in a uniform transmission rate, but error correction is completely dependent upon ECC cores, that is, an RS codec (PI and PO).

In order to attain a high density DVD, a laser spot of a DVD must be reduced to approximately a half that of a conventional DVD and a numerical aperture (NA) of a lens must be increased to make a transparent film of a laser incident plane thinner. Thus, foreign matter causing short burst errors, such as dust, or a scratch causing long burst errors, is

relatively increased, thereby disabling from carrying out error correction processing using a conventional error correction system.

SUMMARY OF THE INVENTION

5 To solve the above-described problems, it is an object of the present invention to provide an interleaving method, which can improve an error correction capability in a high density DVD.

To accomplish the above object, there is provided an interleaving method for correcting short burst errors in a high density digital versatile disk (DVD), the method comprising the steps of merging a plurality of error correction code (ECC) blocks, each having a predetermined size, in a horizontal direction, to form a merged ECC block, and storing the merged ECC block in a buffer in units of a predetermined number of rows and interleaving the ECC block in units of a predetermined number of bytes in accordance with a predetermined interleaving rule.

15 Based on the interleaving rule according to the present invention, 2 ECC blocks are linked together in a row direction to generate a new ECC block, which is then interleaved in units of 2 lines. FIG. 6A shows data arrangement before interleaving, and FIG. 6B shows data arrangement after interleaving.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and advantages of the present invention will become more apparent by describing preferred embodiments in detail thereof with reference to the attached drawings in which:

FIG. 1 is a schematic diagram of a general digital versatile disk (DVD) adaptable to the present invention;

FIG. 2 shows a conventional error correction code (ECC) block in a DVD;

FIG. 3 shows the concept of conventional row interleaving in a DVD;

FIG. 4 is a flow chart showing a method for processing data frames of a high density DVD according to the present invention;

FIG. 5 shows an ECC block in a high density DVD according to the present invention;

FIG. 6A shows the sequence of data before interleaving for every 2 lines, when the interleaving is performed on the ECC block shown in FIG. 5 according to the present invention, and FIG. 6B shows the sequence of data after interleaving the data shown in FIG. 6A according to the present invention;

FIG. 7 shows an exemplary formatting of recording frames in a high density DVD; and

FIG. 8 shows a structure of a data field recorded on a high density DVD.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the present invention will now be described in detail with reference to the accompanying drawings.

FIG. 1 is a schematic diagram of a general digital versatile disk-random access memory (DVD-RAM) adaptable to the present invention. Referring to FIG. 1, the DVD-RAM includes a recording portion in which recording on a disk **110** is performed using a pickup **108**, and a reproduction portion in which reproduction from the disk **110** using the pickup **108**. The recording portion includes a formatter **101**, a scrambler **102**, an ECC encoder **103**, a modulator **104**, a non-return-to-zero inverse (NRZI) encoder **105**, a recording waveform shaper **106**, a laser driver (LD driver) **107**, and a recording phase locked loop (PLL) **109**. The reproduction portion includes a radio frequency amplifier (RF-AMP) **111**, an automatic gain control circuit (AGC) **112**, a pre-equalizer (PRE-EQ) **113**, a determiner **114**, a reproducing PLL **115**, an analog-to-digital converter (ADC) **116**, an equalizer (EQ) **117**, a Viterbi detector **118**, a sync and ID code detector **119**, a demodulator **120**, an ECC decoder **121**, a descrambler **122** and a deformatter **123**.

The formatter **101** receives data streams from an MPEG-2 encoder or a data source to form data having a predetermined format. The ECC encoder **103** performs error correction encoding using Reed-Solomon Product Codes (RS-PC). In the present invention, the ECC encoder **103**, as will be described later, improves an error correction capability by interleaving ECC blocks in units of 4 bytes after forming a new ECC block produced by combining two conventional ECC blocks in a horizontal direction. The modulator **104** performs run-length limited (RLL) encoding to eliminate an unwanted direct current (DC)

component. The NRZI encoder **105** encodes the output of the modulator **104** into an NRZI code. The NRZI coded signal is shaped of a recording waveform by the recording waveform shaper **106** to then drive the LD driver **107** to be recorded on the disk **110** by the pickup **108**. The laser power during recording is greater than that during reproduction, thereby allowing a phase transition of the disk **110**. The recording PLL **109** supplies clock pulses for recording, using wobble pit signals recorded on the disk **110**.

The signals recorded on the disk **110** are read by the pickup **108**, amplified by the RF-AMP **111**, gain-controlled by the AGC **112**, converted into digital signals by the ADC **116** and then applied to the EQ **117**. Here, the output of the AGC **112** is reproduced as clocks by the PRE-AMP **113**, the determiner **114** and the reproducing PLL **115**, and then data is reproduced by the Viterbi detector **118**. The sync and ID code detector **119** detects the sync of a data frame. The demodulator **120** demodulates the reproduced signal. The operation of the demodulator **120** is performed in the reverse direction to that of the modulator **104**. The output of the demodulator **120** is error-corrected by the ECC decoder **121** to then be output as data streams via the descrambler **122** and the deformatter **123**. The operation of the respective parts of the reproducing unit is performed in the reverse direction to that of the recording unit.

FIG. 4 is a flow chart showing a method for processing data frames of a high density DVD according to the present invention. Referring to FIG. 4, in step **401**, an ID error detection code (IED) is added to data ID of 4 bytes. In step **402**, a 6-byte reserve code (RSV) and 2048-byte main data are added to the format constructed in step **401**. In step **403**,

a 4-byte error detection code (EDC) is added to the format constructed in step 402 to complete a data frame. In step 404, the data frame is scrambled. The steps 401 through 403 are performed by the formatter 101 shown in FIG. 1, and the step 404 is performed by the scrambler 102.

Then, in step 405, encoding using RS-PC is performed on the 16 scrambled data frames, and 16 PO portions and 10 PI portions are added, thereby forming one 208×182 byte ECC block. In step 406, two ECC blocks are merged to form a merged ECC block of 208×364 bytes. In step 407, 4-byte interleaving according to the present invention is performed with respect to the merged ECC block (208×364) in units of 2 lines.

After interleaving, the interleaved ECC block (208×364) is formed as 32 recording frames each having a size of merged ECC block of 13×182 . The format of data recorded on the disk is composed of frames each having sync codes corresponding to the respective states, as shown in FIG. 8.

FIG. 5 shows an ECC block in a high density DVD according to the present invention.

The ECC block according to the present invention is produced by merging two conventional ECC blocks in a horizontal direction to have a size of 208×364 bytes. Referring to FIG. 5, Reed-Solomon encoding is performed with respect to a 192×172 data matrix composed of data ranging from B0,0 through B0,171 of the first row to B191,0 through B191,171 of the 192nd row, in column and row directions, PO and PI are interleaved to obtain a 208×172 ECC block, and another ECC block obtained in the same method as the 208×172 ECC block,

is merged in a horizontal direction, thereby forming a new ECC block ranging from B0,0 through B0,363 to B207,0 through B207,363.

With respect to the thus-formed ECC block, as shown in FIG. 6A, data of two rows (2×364) ranging from B0,0 through B0,363 to B1,0 through B1,363, are stored in a buffer, every 4 bytes are grouped and then indices of 0 through 181 are sequentially assigned thereto. Then, as shown in FIG. 6B, the corresponding data are interleaved in units of indices for re-arrangement. In other words, letting m be the index assigned before interleaving and k be the index assigned after interleaving, the following formulae 1 and 2 are satisfied.

[Formula 1]

1) when $t=0$, $k=2m$, where $m=2t$

2) when $t=1, 2, \dots, 22$, $k=2m$, where $m=2t$

$$k=2(m-1)+94, \text{ where } m=2t-1$$

3) when $t=23, 24, \dots, 45$, $k=2(m-45)+1$, where $m=2t-1$

$$k=2(m-46)+93, \text{ where } m=2t$$

[Formula 2]

4) when $t=46, 47, \dots, 68$, $k=2(m-92)+2$, where $m=2t$

$$k=2(m-91)+92, \text{ where } m=2t-1$$

5) when $t=69, 70, \dots, 90$, $k=2(m-137)+3$, where $m=2t-1$

$$k=2(m-138)+95, \text{ where } m=2t$$

6) when $t=91$, $k=2(m-137)+3$, where $m=2t-1$.

wherein reference symbol 't' used in each three equations of the above formulae 1 and 2, denotes a positive integer of greater than or equal to 91 inclusive of 0.

Referring to FIGS. 6A and 6B, a cell assigned with indices 0, 1,..., 181 is data of 4 bytes. In the ECC block as described in FIG. 5, two lines are interleaved in the following order. As shown in FIG. 6A, indices 0 through 90 are sequentially assigned to the first line and indices 91 through 181 are then sequentially assigned to the second line, which leads to findings that the indices originally assigned to data are mixed due to re-arrangement by the interleaving according to the present invention, as shown in FIG. 6B.

When the data sequence shown in FIG. 6B, that is, the data re-arranged after interleaving, with the data sequence shown in FIG. 6A, the initial indices of the first four cells of the first line, 0, 45, 92 and 137, are incremented by two, respectively. That is to say, the initial indices 0, 45, 92 and 137 become 2, 47, 95 and 139, then become 4, 49, 96 and 141,...and finally become 44, 89, 136 and 181. Here, the index value 181 corresponds to the first cell of the second line. Then, the initial indices for the first four cells of the second line, are assigned with 91, 46, 1 and 138 and then incremented by two, respectively. That is, the initial values 91, 46, 1 and 138 are followed by 93, 48, 3 and 140, then by 95, 50, 5 and 142, and finally by 43, 180, 135 and 90.

After the first two rows are interleaved, the rows are inserted again into the original ECC block, and then data of B2,0 through B3,363 of two subsequent rows are interleaved in the same manner as described above. The overall interleaving procedure is repeatedly performed 104 times, thereby completing a Byte Merged Inter-Row Interleaving operation.

FIG. 7 shows an exemplary formatting of recording frames in a high density DVD.

After interleaving, an interleaved ECC block (208×364) is divided into 32 recording frames each having a size of 13×182 . Then, 26 sync frames are added to the 32 recording frames, so that they are recorded as the format after modulation, as shown in FIG. 8.

As described above, according to the present invention, the error correction capability of a high density DVD can be improved by distributing short burst errors horizontally and vertically. Also, according to the present invention, interleaving is performed in part rather than in entirety of an ECC block, thereby reducing the size of a buffer memory for interleaving. Further, since 4-byte interleaving, rather than 1-byte interleaving, is employed, the number of memory addressing operations for interleaving can be reduced. Also, adopting a plurality of buffers for interleaving can advantageously increase the interleaving speed.